APPENDIX K TO THE
PHASE I RFI/RI WORK PLAN FOR RFETS
WALNUT CREEK PRIORITY DRAINAGE (OPERABLE UNIT 6)

HUMAN HEALTH RISK ASSESSMENT
TECHNICAL MEMORANDUM NO. 3
MODEL DESCRIPTION

FINAL

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

ENVIRONMENTAL RESTORATION PROGRAM
DECEMBER 1995

TITLE: TECHNICAL MEMORANDUM NO. 3, MODEL DESCRIPTION

Approved By:

_________________________ _________
Director, Date
EG&G Environmental Restoration Program Department

_________________________ _________
Quality Assurance Program Manager, Date
Data Management and Reporting Services

Effective Date: ______________

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EXECUTIVE SUMMARY

This document provides a description of the models selected to perform groundwater, surface water, and air modeling for Rocky Flats Environmental Technology Site (RFETS) Operable Unit No. 6 (OU6) in support of the Human Health Risk Assessment (HHRA), which is part of the OU6 Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI). This document does not describe the details of the implementation of selected models to the site-specific conditions at OU6; that will be described in detail in the Phase I RFI/RI Report.

The objective of the modeling is to support the HHRA portion of the RFI/RI Report for OU6. This will be accomplished by simulating the transport of chemicals of concern (COCs) from OU6 to potential exposure points for human receptors under present and potential future site conditions.

A conceptual site model (CSM) has been developed to identify and evaluate the chemical source areas, chemical release mechanisms, environmental transport media, potential human intake routes, and potential human receptors at OU6. The purpose of the CSM is to identify human exposure pathways to be quantitatively evaluated in the HHRA. Exposure pathways chosen for evaluation in the risk assessment that include transport media such as groundwater, surface water, and air, may require fate and transport modeling to estimate chemical exposure point concentrations. The following document describes the exposure pathways to be evaluated in the HHRA that will require such modeling and identifies the mathematical models that will be used to estimate exposure point concentrations. The models are based on data that have been collected at the site as part of the Phase I RFI/RI for OU6.

The following models were selected to meet the requirements and objectives of the modeling study:

- A simple one-dimensional analytical groundwater model will be run to determine the potential for vinyl chloride to migrate directly from the vadose zone into the air.
- The watershed/water quality model HSPF10 for surface water fate and transport.
- The Superfund Exposure Assessment Manual (SEAM) Models for soil gas fate and transport, a box model for onsite ambient air contaminant fate and transport, and Fugitive Dust Model (FDM) for offsite ambient air contaminant fate and transport of OU6 source air emissions.

Data available for use as input for the modeling activities were evaluated based on a review of previous and ongoing investigations and on general literature. Tables 3-1, 3-2, 3-3, and 3-4 summarize the input parameters currently available to estimate model input parameters. Additional site-specific data from the Phase I RFI/RI investigation will be used in the modeling effort once those data become available.

The data presented in Tables 3-1, 3-2, 3-3, and 3-4 are preliminary and, in some cases, are not site-specific. The data values or ranges of values are not intended to be fixed or final. The ranges are presented to convey what is currently known of the potential variability in the parameter values that may be used in the models.

1.0 INTRODUCTION

This document provides a description of the models selected to perform groundwater, surface water, and air modeling for the OU6 HHRA. The results of the modeling will be used as exposure point concentrations in the HHRA, which is part of the OU6 Phase I RCRA RFI/RI. The RFI/RI is being conducted pursuant to the Compliance Agreement between the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the State of Colorado Department of Public Health and Environment, dated July 31, 1986; and the Federal Facility Agreement and Consent Order (FFACO) [known as the Inter-Agency Agreement (IAG)], dated January 22, 1991. The DOE Environmental Restoration Program (ERP) was formed to identify, investigate, and if necessary, remediate contaminated sites at DOE facilities. The program, in fulfilling this mission, addresses RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) issues. In accordance with the IAG, the CERCLA terms "Remedial Investigation" and "Feasibility Study" in this document are considered equivalent to the RCRA terms "RCRA Facility Investigation" and "Corrective Measures Study," respectively.

This technical memorandum (TM) is intended for review in conjunction with the OU6 HHRA Technical Memorandum No. 2, Exposure Scenarios (Appendix J of the OU6 Work Plan), which provides additional information or details on the exposure scenarios to be used for OU6.

The remainder of Section 1.0 includes a discussion of the purpose of this TM, the objectives of the modeling activities (Section 1.1), and a brief reference to the site location and general site conditions (Section 1.2). Section 2.0 briefly summarizes the OU6 conceptual site model and exposure pathways to be evaluated in the risk assessment for OU6, and Section 3.0 presents descriptions of the selected models for groundwater, surface water, and air and a summary of model input parameter values. Section 4.0 presents a summary, and Section 5.0 is a list of references used in preparing this TM.

1.1 PURPOSE AND SCOPE

The purpose of this document is to provide a description of appropriate groundwater, surface water, and air models for use at OU6. This document fulfills the IAG requirements (IAG 1991, Section VII.D.1.b) that state:

> "... DOE shall submit for review and approval a description of the fate and transport models that will be utilized, including a summary of the data that will be used with these models. Representative data shall be utilized, and the limitations, assumptions and uncertainties associated with the models shall be documented."

The model selection process focuses on models appropriate for simulating processes affecting the migration of contaminants through the saturated zone, the unsaturated zone, surface water, and the airborne transport of contaminants. Model selection is based on the general site conditions outlined in the Phase I RFI/RI Work Plan for OU6 (DOE 1992a) and the OU6 Exposure Assessment Technical Memorandum. Site-specific data will be incorporated into the models.

Modeling activity quality assurance is covered by the site-wide quality assurance plan (EG&G 1991a). Modeling quality assurance includes model verification, checks on calculations, and technical review of modeling methods, assumptions, results, and interpretations.

The objective of the modeling is to support the HHRA portion of the RFI/RI Report for OU6. This will be accomplished by simulating the transport of COCs from OU6 to potential exposure points for human receptors under present and potential future site conditions.

1.2 SITE LOCATION AND GENERAL SITE CONDITIONS

A detailed description of the site location and general site conditions for the RFETS is included in Sections 1.0 and 2.0 of the Phase I RFI/RI Work Plan for OU6 (DOE 1992a). In addition, the HHRA Technical Memorandum No. 2, Exposure Assessment for OU6 (Appendix J to the OU6 Work Plan), contains any new or revised site information that differs from that presented in the work plan.

2.0 GENERAL CONCEPTUAL MODEL OF OU6

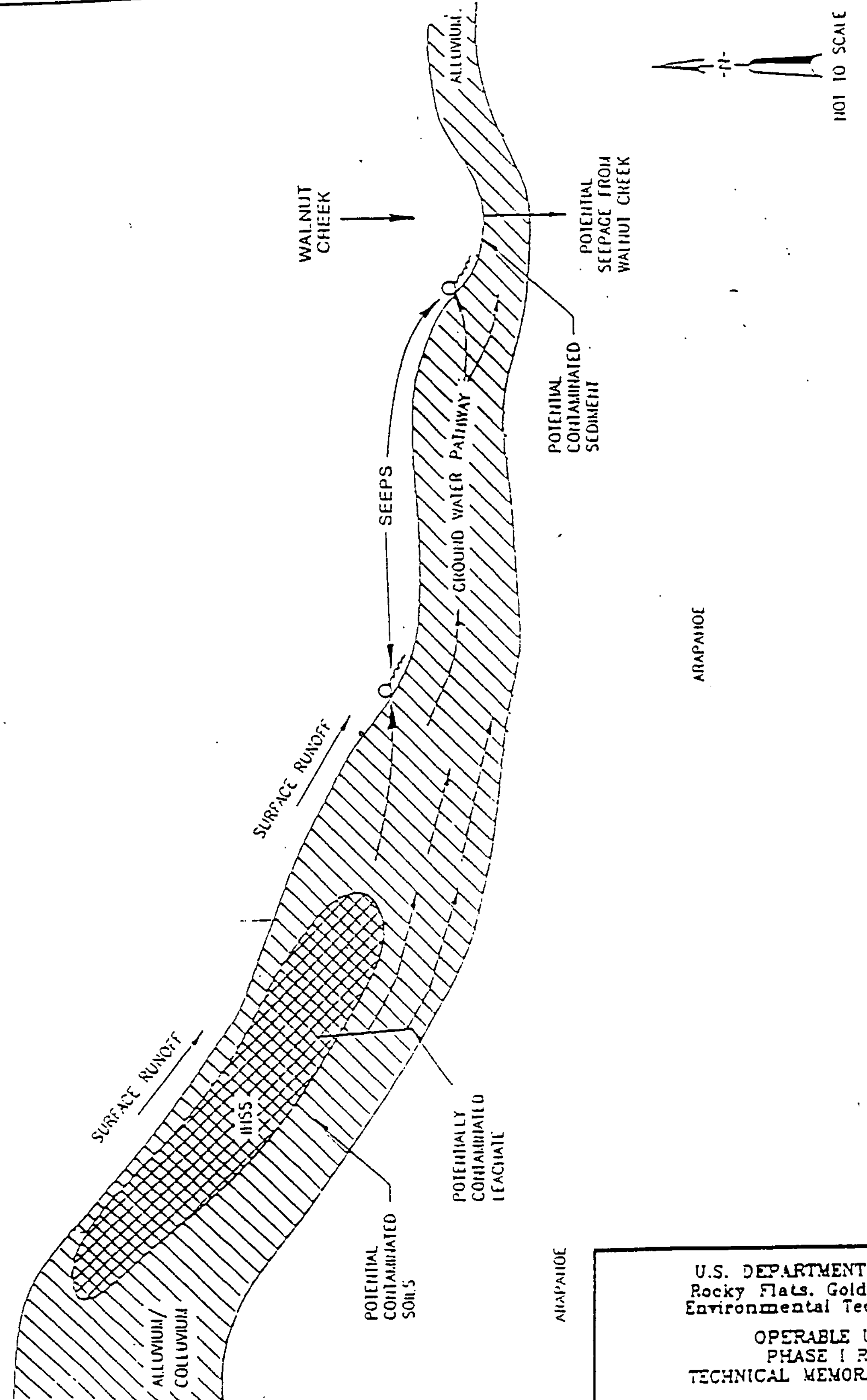
This section discusses the general use of a conceptual site model (CSM) at OU6. A CSM is a schematic representation of the chemical source areas, chemical release mechanisms, environmental transport media, potential human intake routes, and potential human receptors. The purpose of the CSM is to provide a framework for problem definition, to identify exposure pathways that may result in human health risk, to aid in identifying data needed to quantify potential exposures, and to aid in identifying effective cleanup measures, if necessary, that are targeted at significant contaminant sources and exposure pathways.

An exposure pathway describes a specific environmental pathway by which an individual can be exposed to chemical constituents present at or originating from a site. A completed exposure pathway includes five necessary elements: source of chemicals, mechanism of chemical release, environmental transport medium, exposure point, and human intake route. Each one of these five elements must be present for an exposure pathway to be complete. An incomplete pathway means that no human exposure can occur. Only potentially complete pathways will be addressed in the HHRA for OU6. A detailed summary of potentially exposed human receptor populations and exposure pathways developed for each Area of Concern in OU6 is presented in the OU6 HHRA Technical Memorandum No. 2, Exposure Assessment (Appendix J to the OU6 Work Plan).

An exposure point is a specific location where human receptors can come into contact with site-related chemicals. The objective of this TM is to identify fate and transport models that will be used to calculate exposure point concentrations for the HHRA. Exposure pathways that may transport COCs from OU6 to potential human exposure points are presented in the OU6 HHRA Technical Memorandum No. 2, Exposure Assessment. The environmental media associated with exposure pathways that will require fate and transport modeling are groundwater, surface water, and air.

Groundwater

Figure 2-1 illustrates the general conceptual model for groundwater and surface water pathways at OU6. Groundwater flows and chemicals migrate from potentially contaminated soils within an Individual Hazardous Substance Site (IHSS), into the surrounding Rocky Flats Alluvium and colluvium. Potentially contaminated groundwater then migrates out of seeps along valley slopes as surface water or near-surface groundwater in the colluvium to the creeks. South and North Walnut creeks, as well as the unnamed northern tributary to Walnut Creek, then transport possible contaminants downstream via surface water processes.



U.S. DEPARTMENT OF ENERGY
Rocky Flats, Golden, Colorado
Environmental Technology Site

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CONCEPTUAL MODEL FOR GROUNDWATER AND SURFACE WATER

Figure 2-1

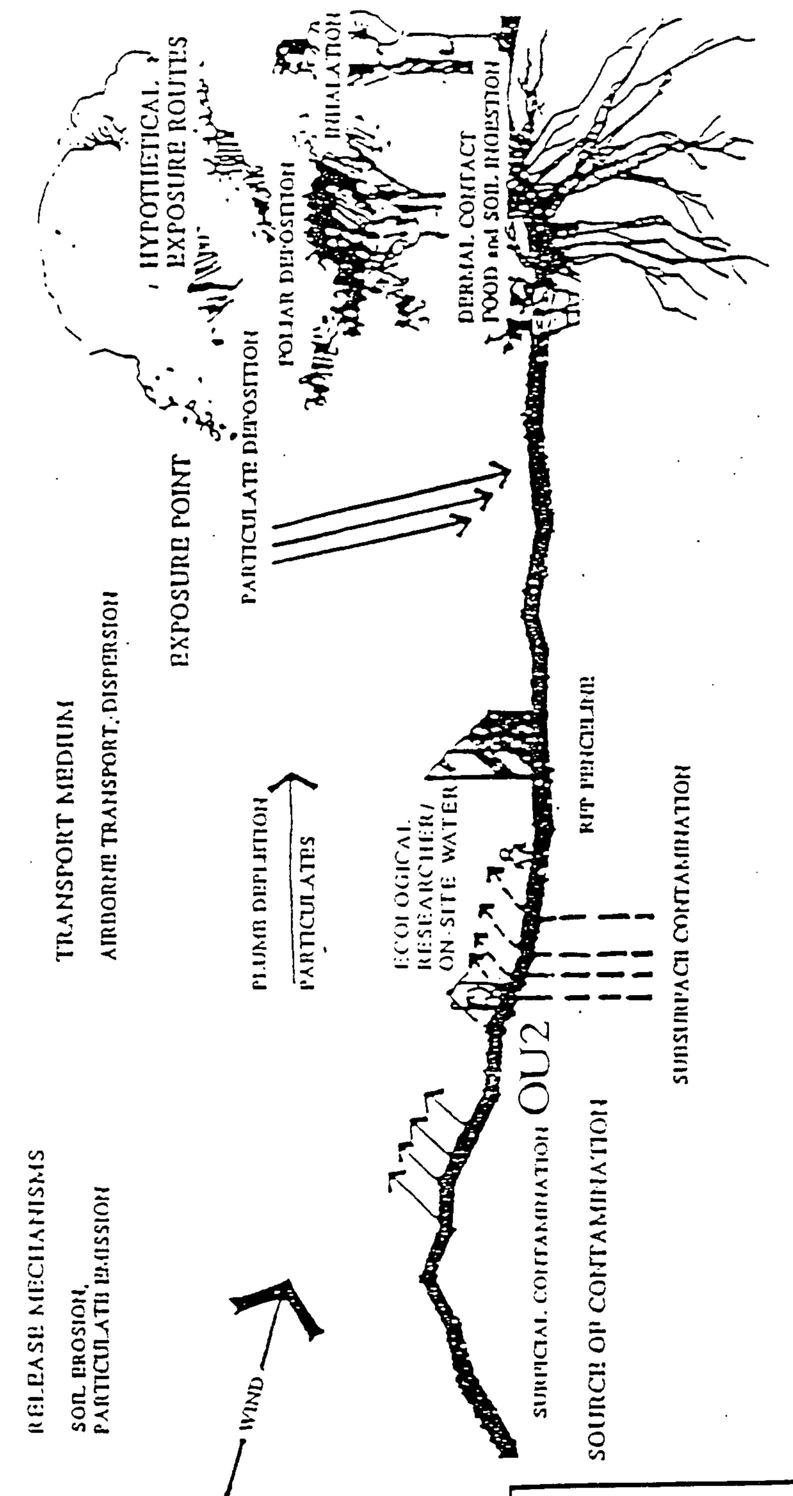
OCTOBER 1994

Surface Water

The pathways of interest for surface water are related to ingestion of or dermal contact with surface water containing suspended sediment and/or site-related chemicals potentially transported to surface water. Stormwater runoff may transport contaminated soils to surface waters through erosion, with subsequent transport to downstream receptors. Surface waters and suspended sediments may also be impacted from the discharge of contaminated groundwater via seeps and springs. Figure 2-1 is a conceptual model for groundwater and surface water illustrating these pathways.

Air

The air emissions and dispersion models selected to assess air contaminant concentrations at sensitive receptors will estimate exposure point concentrations for the exposure pathways associated with air transport. Volatile organic compounds (VOCs) may be transported through the vadose zone from underlying soils and be subsequently entrapped within a hypothetical building located on the surface of OU6. Chemicals in surface soils may be transported via fugitive dust emissions from OU6 to onsite and offsite receptors. Fugitive dust emissions from OU6 may also result in deposition of chemicals in airborne particulates on surface soils and plants. Potential chemical intake and corresponding risks associated with these media will also be evaluated. A general conceptual model for airborne exposure pathways is shown on Figure 2-2.



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CONCEPTUAL MODEL FOR
AIRBORNE EXPOSURE PATHWAYS

Figure 2-2

OCTOBER 1994

OU6RI229

3.0 MODEL DESCRIPTIONS

This section specifies the models to be used in characterizing and predicting exposure point concentrations at specific receptor locations for the OU6 HHRA. The considerations for model selection and the basis for selecting the chosen models are also discussed.

The term "model" refers to computer codes or a set of equations that can be used to mathematically represent site conditions and simulate media behavior (e.g., groundwater flow) and contaminant fate and transport in the model domain. The models will incorporate site-specific data to allow simulation of site-specific conditions and behavior. The combination of a computer code and the necessary site-specific data will be referred to as a "site-specific model."

3.1 GENERAL CONSIDERATIONS FOR MODEL SELECTION

According to Bond and Hwang (1988) and van der Heijde and Park (1986), the following issues should be considered when selecting groundwater models for simulating conditions at a site: (1) the objectives of the project, (2) the physical and chemical conditions of the site, and (3) the requirements for implementing the models. Although the discussions presented by Bond and Hwang and van der Heijde and Park were directed at groundwater models, it is reasonable to apply the same considerations to surface water and air models.

The OU6 modeling objective (Issue No. 1) is to simulate the transport of COCs to potential human receptor locations for risk assessment purposes. The physical and chemical conditions of the site (Issue No. 2) have been and are continuing to be characterized as part of the ongoing Phase I RFI/RI process. Models selected should be capable of incorporating key onsite transport processes. Requirements for implementing the models (Issue No. 3) include: (1) the availability of the model, (2) the degree and nature of documentation, (3) the extent of peer review of the model, and (4) the nature of model verification and testing. (Model verification is the process of verifying that the model results are numerically correct and involves an independent check of the calculations performed by the model.)

Based on the issues described above, a set of criteria was developed for selecting the models to be used at OU6. Model selection was based on the following five criteria:

1. The selected models should be able to incorporate key processes known to occur at the site.
2. The selected models should be able to satisfy the objectives of the study.
3. The selected models should be verified using published equations and solutions.

4. The selected models should be complete and well documented and preferably available in the public domain.
5. The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

These five criteria were used as the basis for selecting the groundwater, surface water, and air models to be used for OU6. The following sections discuss the selected models relative to their ability to satisfy the identified selection criteria.

All mathematical models have limitations and uncertainties associated with assumptions inherent in the models. This is true for the models selected for use for OU6. However, it is believed that the selected models presented herein are the most appropriate models available for use for OU6 and that the associated limitations and uncertainties are acceptable.

3.2 GROUNDWATER CONTAMINANT FATE AND TRANSPORT MODEL

Groundwater contaminant conditions in OU6 have been evaluated based on hydrogeologic conditions, spatial and temporal distributions of COCs, potential sources of contamination, and the mobility and behavior of COCs. Based on this evaluation, groundwater contaminant fate and transport modeling strategies to support the OU6 HHRA have been determined. The detailed discussion of the modeling strategies is presented as follows.

Groundwater COCs were identified in Technical Memorandum No. 4, Human Health Risk Assessment for Walnut Creek Priority Drainage, Operable Unit No. 6 (Appendix L of the OU6 Work Plan). Based on a review of the spatial distribution and concentrations of these COCs, three major groundwater contaminant concerns which potentially need to be modeled were identified:

- TCE and other VOCs in the Trench Area near the landfill pond (OU7)
- Nitrite/nitrate in the North Walnut Creek Drainage upgradient of Pond A-1
- Vinyl chloride and other VOCs in the South Walnut Creek Drainage upgradient of Pond B-1.

An evaluation of existing data and other pertinent information has led to the following conclusions:

1. Modeling of TCE and other VOCs in the Trench Area will be conducted as part of the OU7 closure study.

2. The sources and major portion of the nitrite/nitrate plume are located in the Solar Pond Area (OU4). It would be more appropriate for this plume to be modeled as part of the OU4 RFI/RI.

3. A screening level analytical groundwater model may be necessary to simulate potential migration of vinyl chloride from well 3585 downgradient to South Walnut Creek. This model (or a combination of different models) should be able to simulate both lateral migration in groundwater and volatilization from groundwater to soil gas in the vadose zone.

Trench Area VOC Modeling

In the Trench Area (IHSSs 166.1, 166.2, 166.3, and old 167.4) elevated concentrations of VOCs are detected only in wells located on the north side of the groundwater divide, which follows the topographic divide between the North Walnut Creek Drainage and the Unnamed North Tributary Drainage. The groundwater flow gradient indicates that contaminants will potentially migrate towards the landfill pond. As seen in Figure 3-1, concentrations of VOCs in groundwater samples collected from some of the Trench Area wells are relatively great. The VOC with the highest concentrations was TCE, ranging from 26 to 150 μg/L in well 7287. A numerical groundwater model is currently being developed for OU7 which covers the major portion of the Trench Area. The OU6 wells that will be included in this model are 7087, 7287, B206489, B206589, B206689, B206889, 4087, 76792, and 76992. Because OU7 is developing this model, it is not necessary for OU6 to duplicate this effort, especially.

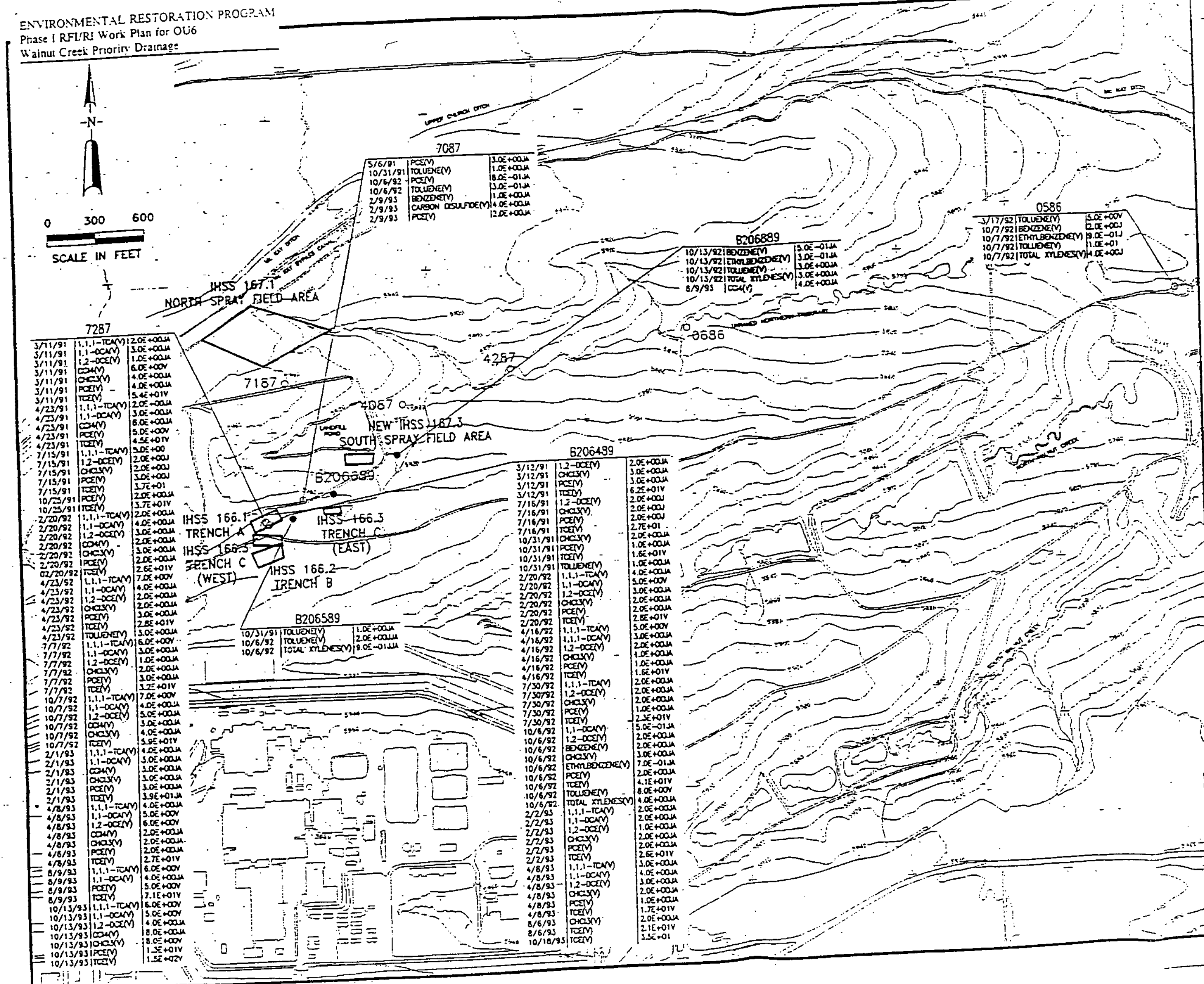
Nitrite/Nitrate Modeling

During the OU6 samping effort from the 1st quarter 1991 to 4th quarter 1993, continuously large concentrations of nitrite/nitrate, ranging from 30 to 1,700 mg/L, were observed in valley fill wells and bedrock wells in the area upgradient of the A-series ponds. These wells are 1786, 1586, B208589, B210489, B208289, B209689, and P210089; the nitrite/nitrate data for groundwater samples collected from these wells is shown on Figure 3-2.

Evidence presented in the 1991 Annual RCRA Groundwater Monitoring Report for Regulated Units at Rocky Flats Plant (EG&G 1992) indicates that the sources of nitrite/nitrate are located within the Solar Ponds Area (OU4). These data suggest that the elevated nitrite/nitrate concentrations detected in the groundwater samples collected in the North Walnut Creek area are derived from OU4 and that these data represent the front of the nitrite/nitrate plume. The majority of the plume is likely within OU4 and a complete groundwater model should be developed as a part of the OU4 RFI/RI. This model should cover the entire nitrite/nitrate plume in OU4 and OU6. A discussion of nitrite/nitrate migration will be included in the RFI/RI report for OU6.

Appendix K
Page:

ENVIRONMENTAL RESTORATION PROGRAM
Phase I RFI/RI Work Plan for OU6
Walnut Creek Priority Drainage



EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITES

0586 ○ UHSU MONITORING WELL (ALLUVIAL)

B206889 ● UHSU MONITORING WELL (BEDROCK)

UHSU = UPPER HYDROSTRATIGRAPHIC UNIT

DRAFT

0586 ← LOCATION

2/26/92 | |

SAMPLE DATE — ANALYTE — ANALYTE CONCENTRATION (ug/l), LAB QUALIFIERS AND VALIDATION CODES

(V) - VOLATILE

NOTES:
1. ALL ANALYTE CONCENTRATIONS ARE REPORTED IN ug/l (parts per billion). ANALYTE ABBREVIATIONS, LAB QUALIFIERS, AND VALIDATION CODES ARE PRESENTED ON FIGURE 4.2-1
2. ALL LOCATIONS SHOWN ON THIS MAP WERE SAMPLED. RESULTS ARE SHOWN ONLY WHERE THE CHEMICALS WERE DETECTED.
• INDICATES THIS RESULT IS AN AVERAGE OF THE REAL AND DUPLICATE SAMPLE RESULTS.

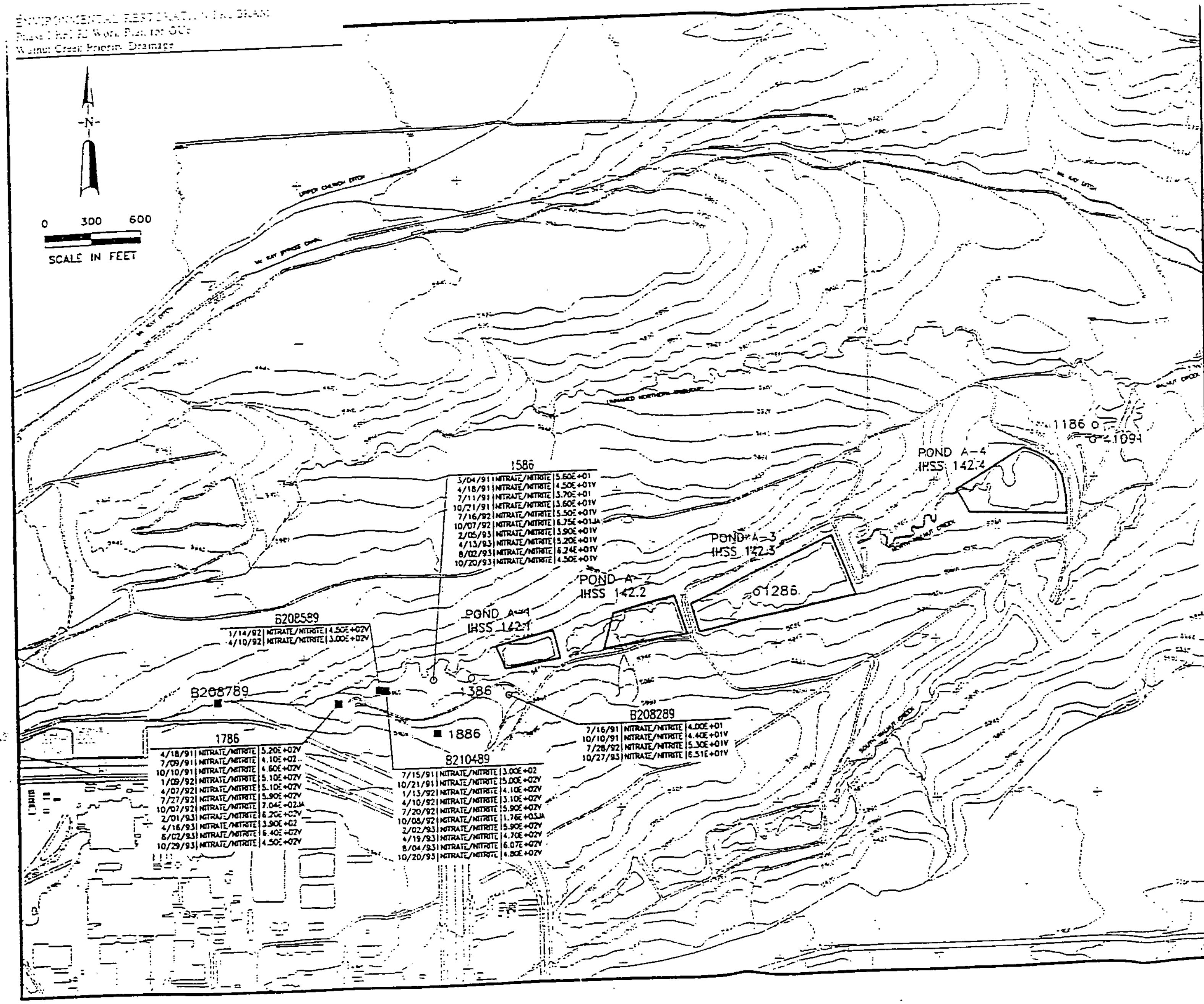
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 6
PHASE I RFI/RI REPORT

ORGANIC COMPOUNDS
AREA 1 (UNNAMED TRIBUTARY DRAINAGE)
UHSU GROUNDWATER
1st QUARTER 1991 — 4th QUARTER 1993

Figure 3-1

AUGUST 1994



EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITES

1186 ○ UHSU MONITORING WELL (ALLUVIAL)

1886 ■ UHSU MONITORING WELL (COLLUVIAL)

B206289 ○ UHSU MONITORING WELL (BEDROCK)

UHSU = UPPER HYDROSTRATIGRAPHIC UNIT

DRAFT

41091 ← LOCATION

2/26/92 — SAMPLE DATE; ANALYTE; ANALYTE CONCENTRATION (mg/l), LAB QUALIFIERS, AND VALIDATION CODES

NOTES:

1. ALL ANALYTE CONCENTRATIONS ARE REPORTED IN mg/l (parts per million). ANALYTE ABBREVIATIONS, LAB QUALIFIERS, AND VALIDATION CODES ARE PRESENTED ON FIGURE 4.2-1
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• INDICATES THIS RESULT IS AN AVERAGE OF THE REAL AND DUPLICATE SAMPLE RESULTS.

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO. 6
PHASE I RFI/RI REPORT

NITRATE/NITRITE
AREA 2 (NORTH WALNUT CREEK DRAINAGE)
UHSU GROUNDWATER
1st QUARTER 1991 — 4th QUARTER 1993

Figure 3-2

AUGUST 1994

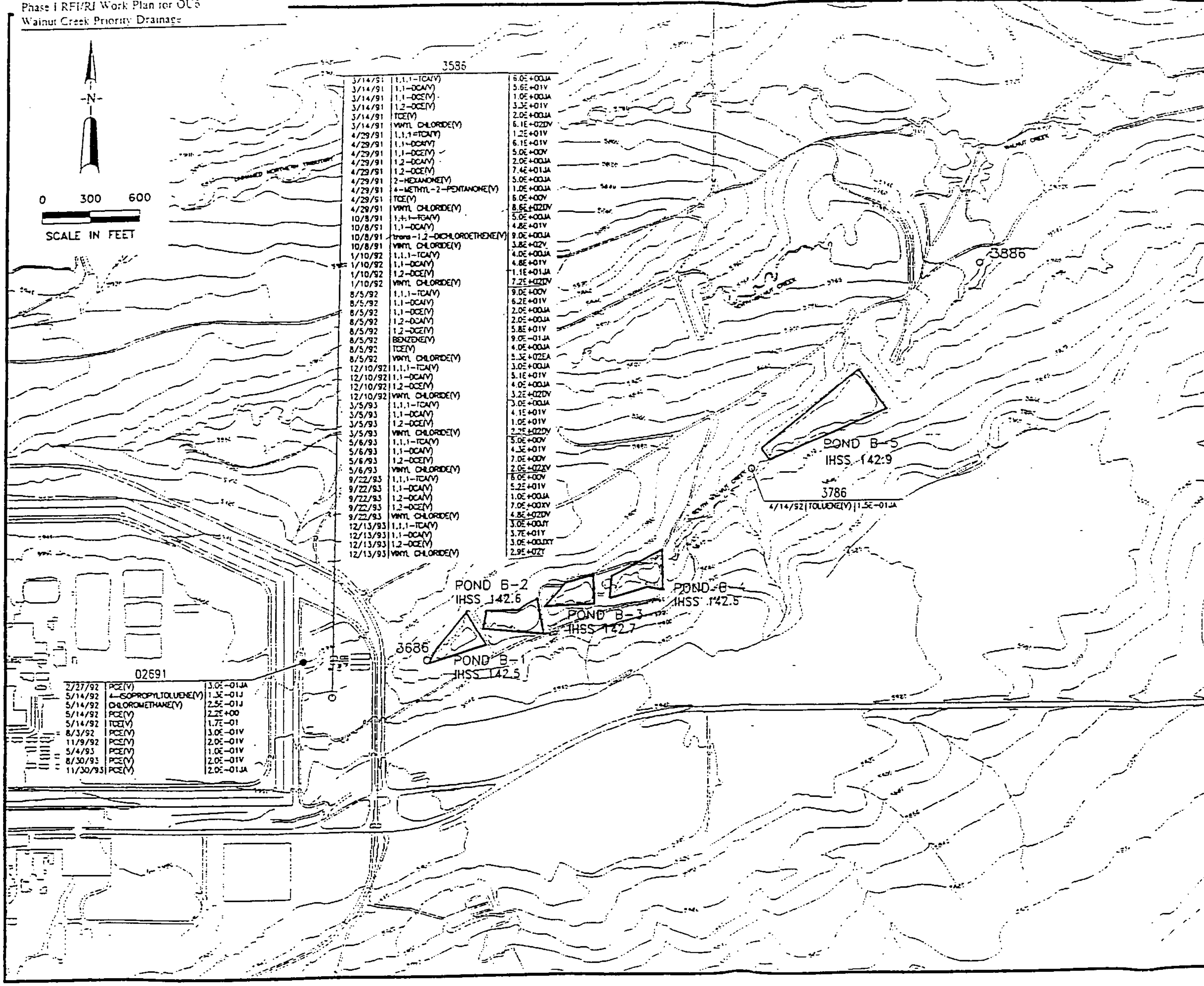
Vinyl Chloride Modeling

During the OU6 sampling effort from 1st quarter 1991 to 4th quarter 1993, large concentrations of vinyl chloride (VC), ranging from 220 to 860 $\mu g/L$, have been continuously observed in well 3586 (screened in valley fill alluvium). However, no VC has been detected in upgradient or downgradient wells (including well 3686, which is also screened in valley fill alluvium and located approximately 600 feet downgradient) (Figure 3-3).

Although the source(s) of these isolated VC concentrations in well 3586 is uncertain, available evidence does provide strong indications of why this solvent is present at this location. VC is transformed rapidly from its parent products (i.e., PCE-TCE-1,1-DCE) under anaerobic conditions (in the presence of anaerobic bacteria). Groundwater data collected within OU2, which is upgradient of Well 3586, show that these parent products are present in abundance and indicate that OU2 may be a probable source for the solvents from which VC is transformed. Other possible upgradient sources include the Triangle Area (OU6) and the Industrial Area.

However, no VC has been detected in association with its parent products in upgradient groundwater. It is assumed that, in general, the upgradient subsurface environment is not anaerobic, or unfavorable for biotransformation of the parent products to VC. The circumstances that may have created the favorable anaerobic subsurface environment isolated around Well 3586 remain undefined. It is possible that the sewage treatment plant to the north and upgradient of Well 3586 is leaking effluent with the high bacteria counts needed for this transformation into the groundwater, or that sewage transmission pipes going into the plant may be leaking. Either one of these scenarios, or perhaps one unconsidered, could be creating the required anaerobic conditions for the biotransformation to occur.

Evaluation of the potential for downgradient migration of VC could be performed by a simple analytical groundwater model. This analytical model (or models) should be able to incorporate both groundwater transport and volatilization. It is suspected that VC may completely volatilize before reaching downgradient wells. This assumption is based on the following rationale: (1) VC has great potential to be volatilized, having a Henry's law constant of 1.22 $atm\text{-}m^3/mol$ at 10°C (Montgomery and Weikom 1989); (2) the water table in the valley fill alluvium in the vicinity of well 3586 is shallow, within 8 feet of the ground surface; and (3) observations recorded during the 4th quarter of 1993 sampling at well 3586 show very large gas concentrations of VOC, with initial head space concentrations of 104 mg/L and 2.8 mg/L about 5 minutes later. The second head space concentration may represent the volatilization rate under ambient conditions.



3586

3/14/91	1,1,1-TCA(V)	6.0E+00JA
3/14/91	1,1-DCA(V)	5.6E+01V
3/14/91	1,1-DCE(V)	1.0E+00JA
3/14/91	1,2-DCE(V)	3.3E+01V
3/14/91	TCE(V)	2.0E+00JA
3/14/91	VINYL CHLORIDE(V)	6.1E+02DV
4/29/91	1,1,1-TCA(V)	1.2E+01V
4/29/91	1,1-DCA(V)	6.1E+01V
4/29/91	1,1-DCE(V)	5.0E+00V
4/29/91	1,2-DCA(V)	2.0E+00JA
4/29/91	1,2-DCE(V)	7.4E+01JA
4/29/91	2-HEXANONE(V)	5.0E+00JA
4/29/91	4-METHYL-2-PENTANONE(V)	1.0E+00JA
4/29/91	TCE(V)	6.0E+00V
4/29/91	VINYL CHLORIDE(V)	8.6E+02DV
10/8/91	1,1,1-TCA(V)	5.0E+00JA
10/8/91	1,1-DCA(V)	4.8E+01V
10/8/91	trans-1,2-DICHLOROETHENE(V)	9.0E+00JA
10/8/91	VINYL CHLORIDE(V)	3.8E+02V
1/10/92	1,1,1-TCA(V)	4.0E+00JA
1/10/92	1,1-DCA(V)	4.8E+01V
1/10/92	1,2-DCE(V)	1.1E+01JA
1/10/92	VINYL CHLORIDE(V)	7.2E+02DV
8/5/92	1,1,1-TCA(V)	9.0E+00V
8/5/92	1,1-DCA(V)	6.2E+01V
8/5/92	1,1-DCE(V)	2.0E+00JA
8/5/92	1,2-DCA(V)	2.0E+00JA
8/5/92	1,2-DCE(V)	5.8E+01V
8/5/92	BENZENE(V)	9.0E-01JA
8/5/92	TCE(V)	4.0E+00JA
8/5/92	VINYL CHLORIDE(V)	5.3E+02EA
12/10/92	1,1,1-TCA(V)	3.0E+00JA
12/10/92	1,1-DCA(V)	5.1E+01V
12/10/92	1,2-DCE(V)	4.0E+00JA
12/10/92	VINYL CHLORIDE(V)	3.2E+02DV
3/5/93	1,1,1-TCA(V)	3.0E+00JA
3/5/93	1,1-DCA(V)	4.1E+01V
3/5/93	1,2-DCE(V)	1.0E+01V
3/5/93	VINYL CHLORIDE(V)	2.7E+02DV
5/6/93	1,1,1-TCA(V)	5.0E+00V
5/6/93	1,1-DCA(V)	4.3E+01V
5/6/93	1,2-DCE(V)	7.0E+00V
5/6/93	VINYL CHLORIDE(V)	2.0E+02XV
9/22/93	1,1,1-TCA(V)	6.0E+00V
9/22/93	1,1-DCA(V)	5.2E+01V
9/22/93	1,2-DCA(V)	1.0E+00JA
9/22/93	1,2-DCE(V)	7.0E+00XV
9/22/93	VINYL CHLORIDE(V)	4.8E+02DV
12/13/93	1,1,1-TCA(V)	3.0E+00JY
12/13/93	1,1-DCA(V)	3.7E+01Y
12/13/93	1,2-DCE(V)	3.0E+00DJY
12/13/93	VINYL CHLORIDE(V)	2.9E+02Y

02691

2/27/92	PCE(V)	3.0E-01JA
5/14/92	4-ISOPROPYLTOLUENE(V)	1.3E-01J
5/14/92	CHLOROMETHANE(V)	2.5E-01J
5/14/92	PCE(V)	2.2E+00
5/14/92	TCE(V)	1.7E-01
8/3/92	PCE(V)	3.0E-01V
11/9/92	PCE(V)	2.0E-01V
5/4/93	PCE(V)	1.0E-01V
8/30/93	PCE(V)	2.0E-01V
11/30/93	PCE(V)	2.0E-01JA

EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITES

3586 ○ MONITORING WELL (ALLUVIAL)

02691 ● MONITORING WELL (BEDROCK)

UHSU = UPPER HYDROSTRATIGRAPHIC UNIT

DRAFT

3586 ← LOCATION

2/25/92 — SAMPLE — ANALYTE — ANALYTE CONCENTRATION (ug/l), LAB QUALIFIERS, AND VALIDATION CODES

(V) – VOLATILE

NOTES:

1. ALL ANALYTE CONCENTRATIONS ARE REPORTED IN ug/l (parts per billion). ANALYTE ABBREVIATIONS, LAB QUALIFIERS, AND VALIDATION CODES ARE PRESENTED ON FIGURE 4.2-1
2. ALL LOCATIONS SHOWN ON THIS MAP WERE SAMPLED. RESULTS ARE SHOWN ONLY WHERE THE CHEMICALS WERE DETECTED.
3. PESTICIDE/PCB ANALYSES WERE PERFORMED AT ONLY LOCATION 02691.

• INDICATES THIS RESULT IS AN AVERAGE OF THE REAL AND DUPLICATE SAMPLE RESULTS.

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PHASE I RFI/RI REPORT

ORGANIC COMPOUNDS
AREA 3 (SOUTH WALNUT CREEK DRAINAGE)
UHSU GROUNDWATER
1st QUARTER 1991 – 4th QUARTER 1993

Figure 3-3

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OU6RI:38 1=600

A simple one-dimensional analytical groundwater model that can incorporate both mechanisms (lateral migration in groundwater and volatilization within the vadose zone) will be developed for OU6. This was done because an analytical groundwater model able to accomodate both mechanisms was not located in the literature. The developed model will include only the most important fate and transport processes (advection in the groundwater system and volatilization in the vadose zone). Adsorption and biodegradation will be ignored based on the physical and chemical properties of VC. Dispersion will also be ignored because one-dimensional dispersion only causes attenuation. If the source concentration is constant, dispersion will only delay the process for the downgradient concentration to approach that constant. Therefore, not simulating dispersion is a conservative methology.

Because VC is a special case COC for OU6 and has been detected at only one location, the risk assessment for this compound will not require a numerical model to project future exposure concentrations. However, an analytical groundwater model simulation will be run to determine the potential for VC to migrate downgradient or to volatize directly from the vadose zone into the atmosphere in the vicinity of the well. Analytical groundwater model simulation results depend on the estimation of related parameters, including hydraulic conductivity, Henry's law constant, air-filled porosity in the vadose zone, and so forth. Because of uncertainly of these parameters, a range of literature values and site-specific estimates of the parameters may be used in the simulation to provide a range of possible results under certain assumptions.

3.3 SURFACE WATER MODEL

3.3.1 Introduction

The surface water model will contribute to the HHRA by simulating the maximum, 30-year average concentration of COCs at receptor sites determined by the HHRA. The Hydrologic Simulation Package for ForTran, version 10 (HSPF10) has been selected for use in the modeling effort.

HSPF10 is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutatns. HSPF10 is the only comprehensive model of watershed hydrology and water quality that integrates the simulation of land and soil runoff processes with in-stream hydraulic and sediment-chemical interactions (Ambrose and Barnwell 1989). Further model selection criteria are discussed in Section 3.3.2.

Potential contaminant fate and transport mechanisms to be modeled include both dissolved and particulate states as related to hillslope, stream, and reservoir processes. Major processes affecting the surface water/sediment contaminant concentrations in OU6 are:

- Precipitation/runoff
- Soil erosion and associated contaminant movement
- Stream and pond hydraulics
- Chemical-specific fate mechanisms

3.3.2 Discussion

Model simulations are driven by meteorological and groundwater/seep inflows, entered as hourly time series. The meteorological time series required include precipitation, air and dew point temperatures, solar radiation, wind speed, lake evaporation, and potential evapotranspiration. Except for the evaporation time series, the time series are obtained from the RFETS meteorological tower as 15 minutes readings and appropriately transformed to a 1-hour interval.

A 1-hour simulation time step has been chosen so that the effects of temporally short, but relatively intense meteorological events will not be obscured, as may occur if the meteorological conditions were considered on a mean daily basis. Outputs can be obtained at any aggregation of the simulation interval. Daily summaries will be used, as 1 hour to 1 hour comparisons of simulated versus observed values requires extremely detailed boundary condition development and determination of localized variations that are beyond the scope of this project. Further, though it would be possible to attempt flow calibration at this time scale, there are no water quality data available at this resolution for use in such a model calibraion.

The lake evaporation time series is calculated by aggregating the other meteorological series to daily values and then calibrating the calculated evaporation to a daily water balace of the Great Western Reservoir. The resulting evaporation time series is then disaggregated to obtain hourly values. It is necessary to use daily values in developing the time series as the calibration criteria against which the time series is developed has a daily resolution.

The potential evapotranspiration (PET) time series is calculated using a standard formula for predicting PET based on regional conditions and local vegetation. The time series is developed directly using an hourly resolution. Actual calibration to RFETS conditions is not possible as necessary studies to perform PET calibrations at RFETS have not been performed. However, there exist sufficient local studies to the required PET equation parameters in the literature and these values have been used in developing the PET time series. The resulting values are then compared against results of other studies as a calibration verification.

The input groundwater inflow and seep time series are needed to satisfy groundwater/surface water mass balance interactions and to simulate the proper antecedent soil moisture conditions. These time series are developed based on field studies and simulations performed in groundwater modeling studies. The seepage time series is a "boundary condition" that may be modified during the calibraion process. The series is not calculated during the actual surface water model runs. Baseflow data are boundary time series that are available from pond operation records and flow recording instrumentation.

General flow calibration will be performed on the July 1, 1989 to June 30, 1993 time frame. This time frame was selected as it encompasses the period where flow data are of sufficient quality for use in the calibration. The 4 years of meteorological data are considered typical for this region and include an event with a greater that 10-year recurrence interval. Detailed flow calibration of low flows and high peak flows will use data beginning May 1, 1993, through the most recently available data. This time period has been chosen because flumes and updated instrumentation were installed in early 1993, permitting the collection of high resolution flow data.

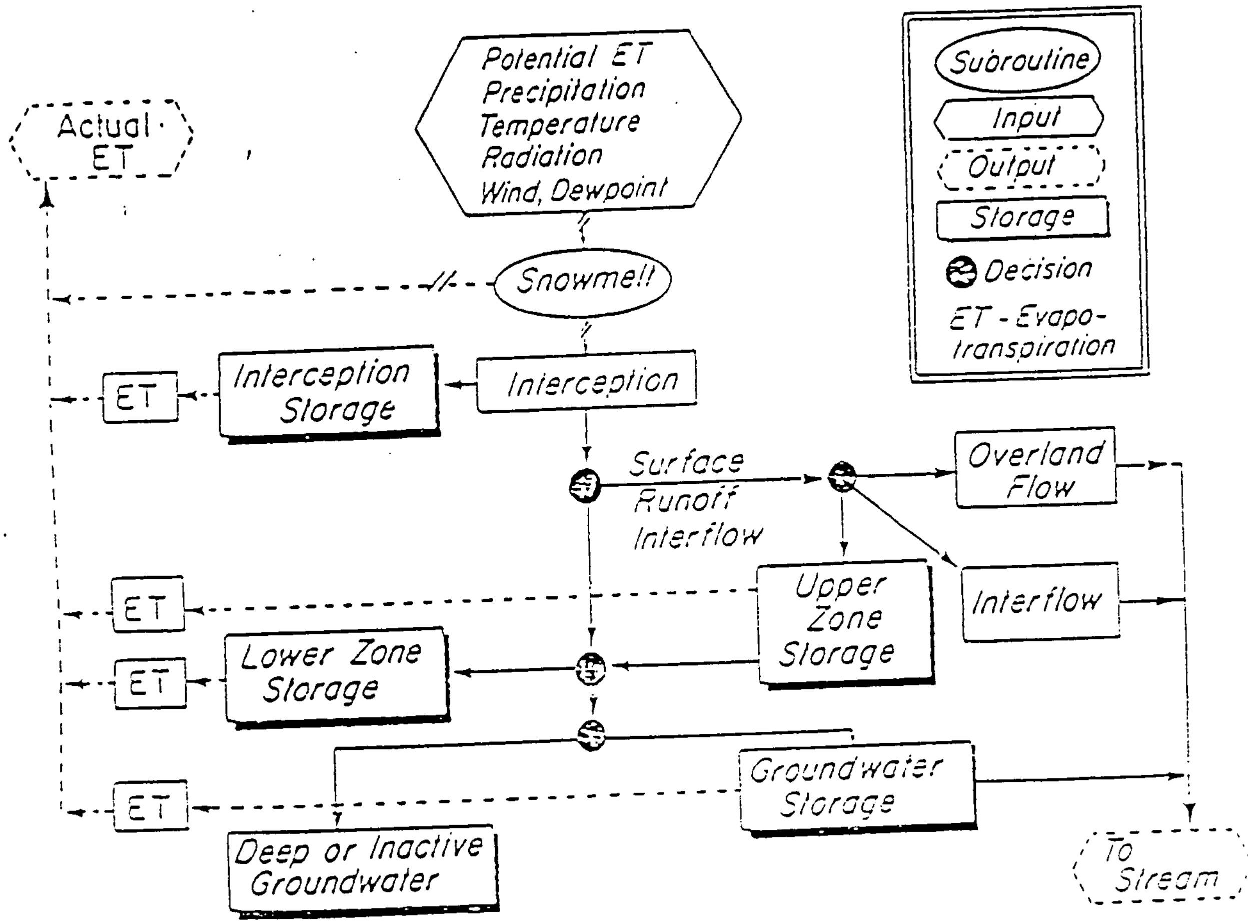
Sediment transport processes are to be calibrated using flow simulations of the last 7 years. This period was selected as meteorological data from the RFETS meteorological tower is readily available and has been verified for this time period. Simulated model deposition will be compared to the actual annual deposition in the A- and B-series ponds, as determined from sampling events during this period. Simulation of suspended sediments will be compared against total suspended solids values obtained during other OUs sampling events.

Multiple 30-year simulations will be performed. The meteorological time series used for the 30-year simulations will be developed by use of the WEPP program, a weather generator. The maximum, single 30-year average of COC concentrations obtained from all the 30-year simulations is then to be used in the HHRA.

The following sections overview how these major processes are treated by HSPF10.

<u>Precipitation/Runoff</u>

Hydrologic simulation is performed using the moisture accounting technique first employed in the Stanford Watershed Model (Figure 3-4). That is, the movement of water into, between, and out of a set of conceptual storages is computed using a fixed time step. Rain and snowmelt are subject to interception. If that storage is full, infiltration occurs. Infiltrated moisture passes to the lower zone or to groundwater storage. Excess moisture either remains on the surface or enters flow paths leading to the upper zone or to interflow. The model regards overland flow as equivalent to that along a plane



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HSPF 9/10
PRECIPITATION/RUNOFF PROCESSES

Figure 3-4

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surface of length, slope, and roughness specified by the user. Evapotranspiration can occur from any of the storages. Details of the Stanford Watershed Model methodology are given by Crawford and Linsley (1966).

Soil Erosion

Soil erosion is simulated as illustrated in Figure 3-5. Erosion can occur either due to particle detachment from rainfall impact and subsequent washoff or as a result of rill and gully scour. Details of the soil erosion methodology used by HSPF10 are given by Donigian and Crawford (1976).

Hydraulics

HSPF10 uses a standard technique for flow routing. The catchment stream network is divided into reaches. Program calculations work from upstream to downstream reaches. The stream network can be of any complexity, even including flows that are split and later recombined farther downstream. Impoundments (ponds, lakes, reservoirs) are also included although it should be noted that HSPF10 assumes such impoundments to be completely mixed; stratification is not modeled.

Pollutant Fate Mechanisms

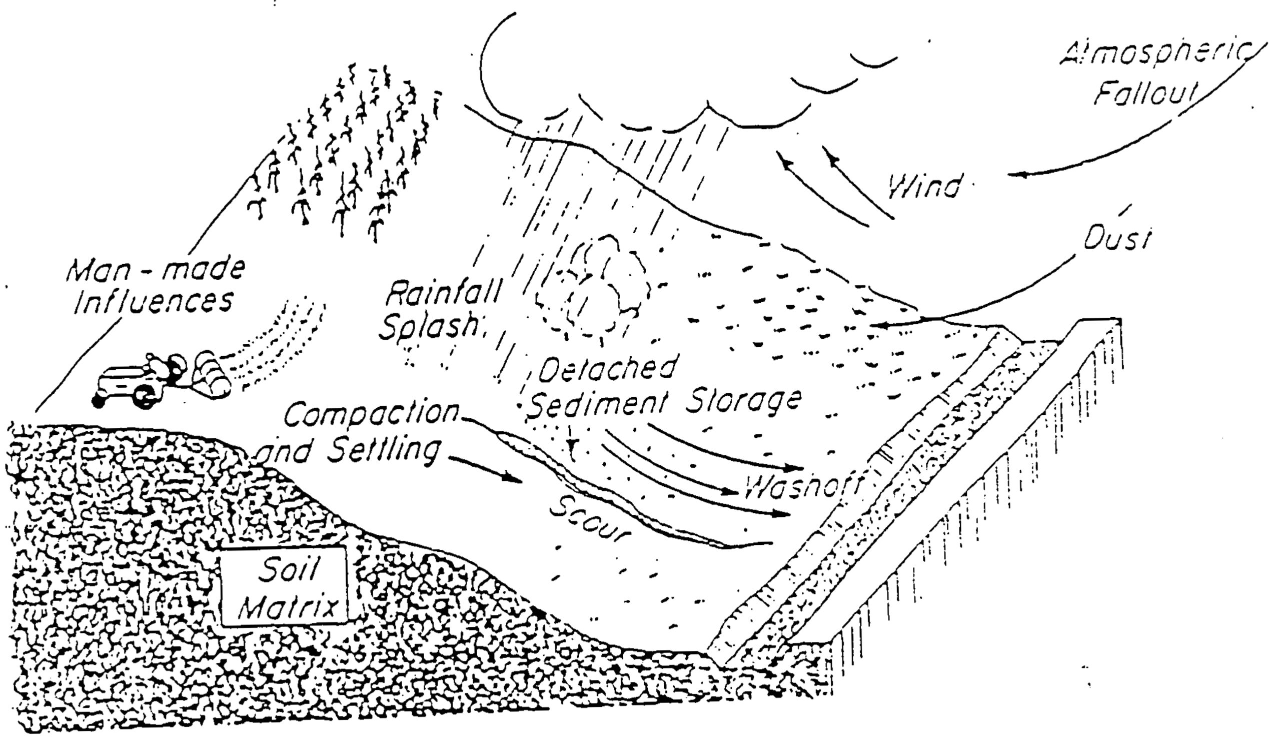
Several important fate mechanisms will affect the chemicals of concern including partitioning as dissolved/particulate phases, interactions between chemicals in the water column and the sediment bed, and any of a number of chemical-specific, physical/chemical/biological processes (e.g., volatilization, biodegradation). HSPF10 can simulate these mechanisms for any generalized quality constituent as illustrated in Figure 3-6.

3.3.3 Model Selection Criteria Evaluation

The HSPF10 model described above was selected because it is believed to best satisfy the five selection criteria. A discussion of how this model meets each of these criteria follows.

Selection Criterion 1 — The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

Key processes associated with surface water aspects of OU6 include, as described before, precipitation/runoff, soil erosion and associated pollutant movement, stream and pond hydraulics, and pollutant-specific fate mechanisms. HSPF10 has extensive capabilities to incorporate these processes; indeed,



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HSPF9/10
SOIL EROSION PROCESSES

Figure 3-5

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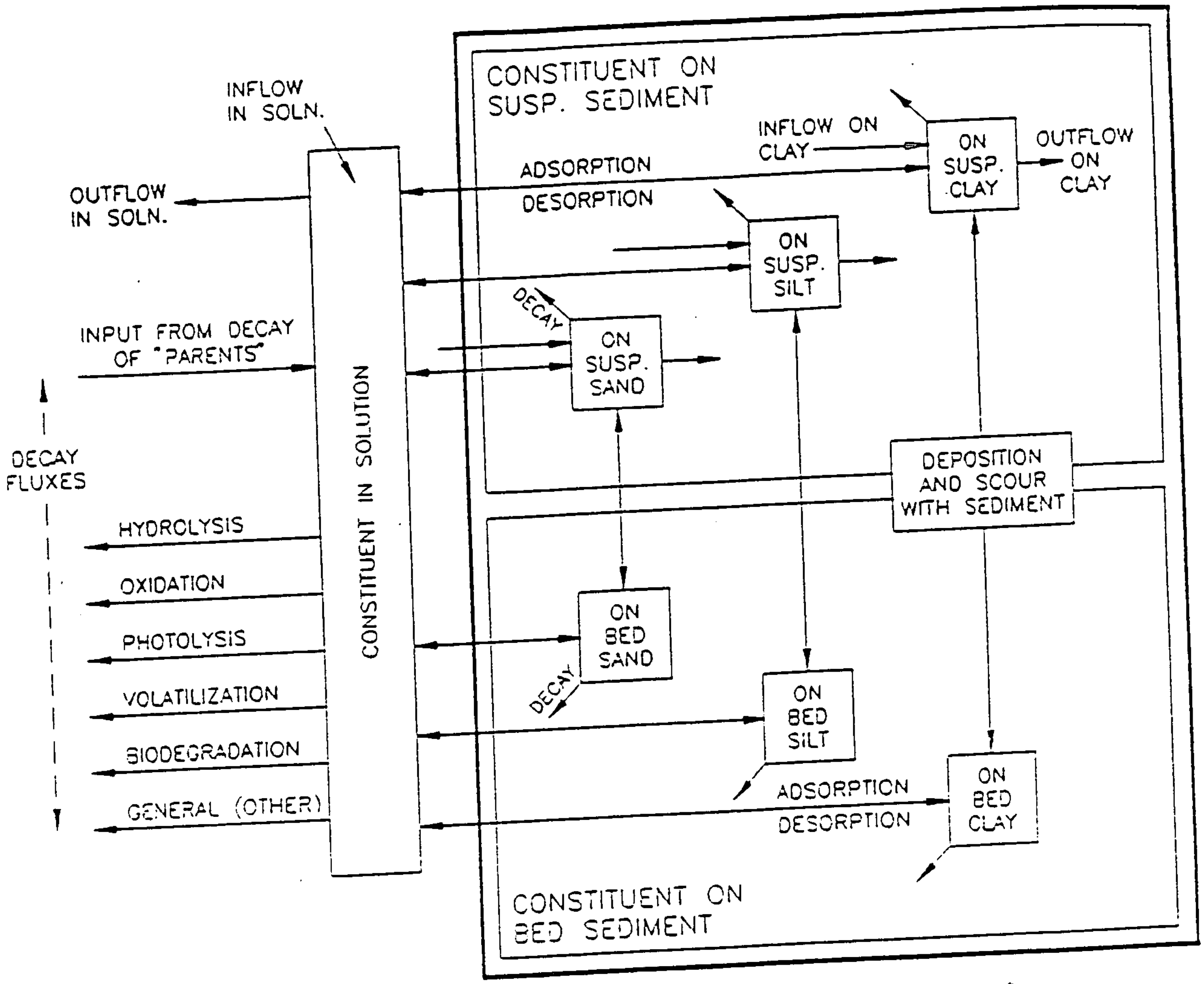

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HSPF 9/10
POLLUTANT FATE MECHANISMS

Figure 3-6

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HSPF10 is the only watershed hydrology/in-stream water quality model known that integrates these processes in a single computer code.

Selection Criterion 2 — The selected models should be able to satisfy the objectives of the study.

The HSPF10 model meets the modeling objective discussed in Section 1.1. To support the risk assessment objective, the model can simulate the transport of chemicals of concern from sources (stormwater runoff, groundwater discharge) to downstream exposure points. The models provide the flexibility needed to estimate risks posed by individual sources, i.e., the risks associated with either stormwater runoff only or groundwater discharge only.

Selection Criteria 3 and 4 — The selected models should be verified using published equations and solutions. The selected models should be complete and well-documented and preferably available in the public domain.

HSPF10 has been validated with both field data and model experiments and has been reviewed by independent experts (Ambrose and Barnwell 1989). It is in the public domain and is distributed and maintained by the EPA Center for Exposure Assessment Modeling in Athens, GA. The original development of HSPF10 began in 1976 and was based on the earlier models: Stanford Watershed Model, Agricultural Runoff Model, and the HSP Quality Model.

Selection Criterion 5 — The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

Although HSPF10 is a comprehensive, mechanistically based model, its modular construct allows it to be tailored to site-specific conditions and objectives. It can be configured to be as detailed or as general as the modeling application dictates by activating more or less modular detail. This flexibility ensures its "cost-effectiveness."

HSPF10 is purely a deterministic model; no stochastic or uncertainty analysis capabilities exist. Uncertainty analysis will be performed outside of the HSPF10 environment by analysis of model prediction errors.

3.4 SOIL GAS TRANSPORT MODEL

3.4.1 Introduction

Soil gas transport modeling will be performed if VOCs are identified in OU6. The modeling would be performed to simulate the diffusion of VOCs from underlying soil gas as a result of volatilization from soil and groundwater contaminants to the OU6 surface just beneath a hypothetical onsite building. The diffusion of VOCs contained in soil gas from the underlying soil and from the underlying groundwater soil interface is estimated by two different equations. An air transport and dispersion model, discussed in Section 3.5, would then be used to estimate airborne VOC concentrations within the building. This activity would support and provide input to the HHRA.

Volatilization From Underlying Soil

Estimates of volatilization from underlying contaminated soil closest to the OU6 surface will be provided by utilization of the Shen Model, modified by Farino (Farino et al. 1983), from Volume II of the Air/Superfund National Technical Guidance Series published by the EPA (EPA 1990). This model is also referred to as the SEAM model, since it is also documented in the Superfund Exposure Assessment Manual (SEAM) (EPA 1988a). This equation is designed for estimating volatilization from underlying soil contamination and the subsequent diffusion of organic vapors to the OU6 surface. This equation has been applied in numerous site investigations and has been validated enough to warrant inclusion in published EPA documents.

The equation used to estimate the steady-state VOC emission rate is as follows:

$$E_i = (AD_i/L)(P_t^{4/3})(C_i)(W_i) \qquad (1)$$

where E_i = emission rate of the contaminant, i (g/sec)
A = surface area (cm^2)
D_i = vapor diffusion coefficient in air (cm^2/sec)
L = surface cap thickness (cm)
P_t = total porosity of the soil cap (cm^3/cm^3)
C_i = saturated vapor concentration of contaminant, i, in the vapor space beneath the surface soil cap (g/cm^3)
W_i = weight fraction of contaminant, i, in the soil (g/g)

C_i, the saturated vapor concentration, is defined by the equation:

$$C_i = PMW_i/RT \qquad (2)$$

where P = vapor pressure of the contaminant (mm Hg)
MW_i = molecular weight of the contaminant (gm/gm-mole)
R = molecular gas constant (62,361 mm Hg-cm^3/gm-mole-K)
T = ambient temperature (K)

Volatilization From Underlying Groundwater

Contributions to surface volatilization emissions from the underlying groundwater will be estimated by using the following equation, adapted from Thibodeaux and Hwang (1982), as presented in SEAM:

$$E_{i(t)} = 2DC_sA/(d + ((2DC_st/C_s) + d^2)^{0.5}) \qquad (3)$$

where $E_{i(t)}$ = average emission rate of contaminant i over time t (g/sec)
D = phase transfer coefficient (cm^2/sec)
C_s = the liquid-phase concentration of contaminant i in the soil (g/cm^3)
C_s = bulk contaminant i concentration in the soil (g/cm^3)
A = contaminated surface area (cm^2)
d = depth of the dry zone at sampling time (cm)
t = time measured from sampling time (sec)

This equation assumes that the soil pore spaces connect with the soil surface, the soil conditions are isothermal and that there is no capillary rise of contaminant. In addition, sufficient liquid contaminant in the pore spaces is assumed to exist so that volatilization will not deplete the reservoir of contaminant to the point where the rate of volatilization is affected. Use of this equation simulates vapor diffusion as being soil-phase controlled and assumes that contaminant concentrations in the soil remain constant until all contaminant is volatilized to the ambient air at the surface. Contaminant release is assumed to occur by the removal of successive unimolecular layers of contaminant from the surface of the "wet" contaminated zone. Thus, over time, a "dry zone" of increasing depth at the soil surface and a wet zone of decreasing depth below the dry zone develops. Concentrations of the contaminant in the soil immediately surrounding the groundwater areas and within the groundwater are used in this estimation method.

The term, D, in the above equation is related to the amount of contaminant i that transfers from the liquid to gas phases and then from the gas phase to diffusion in the surface air and is estimated by:

$$D = D_i(P_t^{4/3})\, H_i' \tag{4}$$

where D_i = vapor diffusion coefficient in air (cm²/sec)
P_t = total soil porosity (dimensionless)
H_i' = Henry's Law constant in concentration form (dimensionless)

Finally, the term, H_i', is estimated by the below equation:

$$H_i' = H_i / RT \tag{5}$$

where H_i = Henry's Law constant of the contaminant i (atm-m³/g-mole)
R = gas constant (8.2×10^{-5} atm-m³/g-mole-K)
T = atmospheric temperature (K)

The Thibodeaux and Hwang equation assumes that the contaminant concentration in the liquid and gas phases in the soil remains constant until all of the contaminant has been volatilized into the surface ambient air. The emission rate, $E_{i(t)}$, is non-zero until the time, t, is equal to a value, t_d, when the soil becomes dry and all contaminant has been volatilized. After time t_d, the volatilization emission rate is assumed to be zero. The estimation of t_d, in seconds, is obtained from the below equation:

$$t_d = ((h^2 - d^2)/2D)(C_s/C_s) \tag{6}$$

where h = depth from the surface to the bottom of the alluvial aquifer (cm)
d = depth of dry zone at sampling time (cm)
D = phase transfer coefficient (cm²/sec)
C_s = bulk contaminant i concentration in soil (g/cm³)
C_s = the liquid-phase concentration of contaminant i in the soil (g/cm³)

Total surface volatilization emissions are then estimated by adding the contributions calculated from Equations (1) and (3). To estimate the diffusion of surface volatilization emissions through the floor of an onsite building, Darcy's law, modified for gas flow across a permeable structure wall, will be used to estimate the volumetric flow rate induced by surface volatile emissions and ambient air entering into the building confines.

This volumetric flow rate is estimated by:

$$Q_{voi} = -k\ A/v\ (dP/dZ) \tag{7}$$

where Q_{voi} = volumetric flow rate of induced by soil gas and ambient air (ft^3/sec)
k = intrinsic permeability of soil (dimensionless)
v = viscosity of the gas (lb/ft-sec)
dP = pressure differential across floor of structure (lb/ft^2)
dZ = thickness of floor (ft)

The concentration of the contaminant within the onsite building is then estimated by:

$$C_{coa} = E_i/(Q_{voi} + Q_b) \tag{8}$$

where C_{coa} = resultant contaminant concentration within the building ($\mu g/m^3$)
E_i = emission rate of the contaminant below the building floor (g/sec)
Q_{voi} = volumetric flow rate induced by the soil gas (m^3/sec)
Q_b = volumetric exchange rate within the building (m^3/sec)

3.4.2 Model Selection Criteria Evaluation

A considerable amount of research and field sampling has been performed to develop models that predict volatilization as a result of soil gas transport. The SEAM models were selected because they are believed to best satisfy the selection criteria defined in Section 3.1.

Selection Criterion 1 — The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

The SEAM models are capable of representing key contaminant processes in estimating soil gas transport. The key processes in the SEAM models include treatment of soil gas diffusion to the surface as a result of underlying soil contamination and also the diffusion from areas of soil and groundwater contamination. The models allow calculation of volatilization of specific components of a complete waste mixture by assuming that Raoult's Law is applicable. A layer of relatively clean and dry soil is assumed to exist between the soil surface and the primary area of underlying soil contamination for the first SEAM equation [Equation (1)]. The depth of this relatively clean layer will be assessed by examining site-specific data. Equation (1) assumes that surface VOC emissions are steady-state and do not decay with time. This assumption is consistent with site observations that there are underlying areas of soil contamination likely to produce surface VOC emissions at a steady rate for an extended period of time. Surface VOC emission contributions from groundwater [Equation (3)] exhibit some dependency with time but will probably not change total surface VOC emissions from a nearly steady state condition.

Examination of onsite data suggests that volatilization as a result of soil gas transport will primarily originate from underlying soil contamination areas closest to the OU6 surface and from the underlying groundwater.

Selection Criterion 2 — The selected models should be able to satisfy the objectives of the study.

The SEAM models estimate surface volatilization from underlying soil gas with consideration of physical and chemical mechanisms. The resulting emission estimates can then be applied to the estimation of exposure point concentrations.

Since air contaminant concentrations are directly proportional to emissions estimates, the effectiveness of potential remediation strategies on sources of volatilization that become part of the air exposure pathways can be readily evaluated. In addition, the effectiveness of potential remediation strategies can be related to underlying soil and groundwater concentrations since these soil gas transport models estimate VOC emissions in nearly direct proportion to underlying soil (waste) and groundwater concentrations.

Selection Criteria 3 and 4 — The selected models should be verified using published equations and solutions. The selected models should be complete and well documented and preferably available in the public domain.

The SEAM models for soil gas transport are widely used and well documented in EPA literature for use in baseline, remedial, and post-remedial scenarios. Equation (1) has refined the widely accepted Farmer model which was one of the first models developed and used to predict VOC emissions from covered landfills. Equation (3) has been widely used for estimation of surface volatilization emissions from old spills and leaks that have migrated below the soil surface. The soil gas transport models appearing in the air pathway analysis series have been subject to extensive validation.

Selection Criterion 5 — The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

These soil gas transport models thoroughly document the proper use of input parameters and demonstrates their use through simulated soil gas transport scenarios. Thus, these models can be easily placed into a spreadsheet format to handle multiple VOCs. Since these models are public domain, there are no procurement or licensing costs for their use.

3.5 AIR TRANSPORT AND DISPERSION MODELS

3.5.1 Introduction

Air dispersion models simulate the transport of the ambient air volatilization rates estimated from the soil gas transport model and particulate matter to specific exposure points for the air exposure pathways designated in Section 2.0. Two different air dispersion models will be utilized according to the following scenarios:

- The transport of VOCs into a building located on the surface of OU6 will be estimated through the use of a box model.
- The transport of particulate matter to onsite receptors both as air contaminant concentrations and air deposition values will be examined through the use of a box model.
- The transport of particulate matter to offsite receptors (i.e.. future and current offsite resident) both as air contaminant concentrations and air deposition values will be evaluated through the use of the Fugitive Dust Model (FDM).

The air contaminant concentration and deposition values provided by the air transport models will support and provide input to the HHRA. Air dispersion modeling will be performed in accordance with procedures described in Volume IV, Procedures for Dispersion Modeling and Air Monitoring for Superfund Air Pathway Analysis. Air/Superfund National Technical Guidance Study Series (EPA-450/1-89-004) and the Guideline on Air Quality Models (EPA-450/2-78-027R). The model for onsite receptors will be a conventional box model that is used widely for immediate exposure scenarios. The models for offsite receptors will be based on Gaussian dispersion and are models approved by EPA. Both models will provide ambient air contaminant concentration and deposition values at previously defined exposure points.

3.5.2 Model Selection Criteria Evaluation

The models selected to be most appropriate for OU6 are a conventional box model for onsite impacts and the FDM for estimation of airborne particulate concentrations and deposition at offsite receptor locations. These models are believed to best satisfy the selection criteria presented in Section 3.1. The box model will be used to model transport of volatiles to a future onsite worker or future resident in a building, and will also be used to model ambient particulate impacts to a future industrial worker, a future onsite resident, and a future ecological worker also located onsite. The FDM will be used to model transport of airborne particulate, both as air contaminant concentrations and as deposition values, at the current and future resident exposure points. A discussion of how each air transport model meets each of these criteria is presented below.

Selection Criterion 1 — The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

The box model and the FDM air models are capable of representing key contaminant processes in estimating air transport and dispersion of air emissions originating from OU6. The box model uses conservation of mass principles to estimate resultant air concentrations for an input emission rate dispersed within a fixed volume with an air exchange rate proportional to the air flow (wind speed) traversing the volume. The box model used for estimating onsite impacts considers the dilution of air emissions within a given volume, defined by the horizontal dimensions of a contaminated area or of an enclosed structure (i.e., building) and the height determined either by surface turbulence or the confined height of a structure. The air exchange rate is dependent upon the utilized wind speed or volumetric air exchange rate, if within the confines of a building. The box model is typically used to estimate onsite air quality impacts only where receptors are located within the immediate areas of the emissions source. The box model estimates impacts by the use of one basic equation that estimates a concentration within a volume centered directly above the emission source of interest that is a function of wind speed, emission rate, and the physical dimensions of the volume.

This equation is:

$$C_i = E_i/UA$$

where C_i = concentration of chemical component i (g/m^3)
E_i = emission rate of chemical component i (g/sec)
U = wind velocity through the volume (m/sec)
A = cross-sectional area of the volume (m^2)

For the building scenario, the box model equation will be modified by using an appropriate value of the passive air exchange rate within the building to estimate a volumetric flow rate that is substituted for the product of the U x A term in the denominator.

The FDM uses Gaussian plume transport and dispersion algorithms with a gradient-transfer deposition and settling algorithm to simulate air contaminant concentration and values from nonpoint sources at distances corresponding to offsite receptors. The FDM was specifically developed for fugitive particulate matter modeling applications (especially wind erosion). The FDM has the capability of assessing up to 100 area sources, 200 receptor points, and 20 particle size classes. FDM is unique in that it can assess rectangularly shaped area sources, not just square or circular. This capability allows FDM to model area sources using a geometry that more closely approximates their actual shape. FDM can utilize constant as well as variable emission rates. FDM can also calculate ground-level concentrations either with settling and deposition functions (as with particulate matter) or without (as with gaseous contaminants). The FDM has the capability to model for short (1-, 3-, 8-, and 24-hour) and long (annual) term averaging periods, and uses meteorological data in either hourly or Stability Array (STAR) formats.

By using the AP-42 emission models (EPA 1988c) for fugitive particulate emission estimation, the FDM model is not required to apply correction factors to account for varying types of land surfaces. However, the FDM will allow for the direct computation of the contaminant emission rate as a function of the wind speed or allow the user to input a constant emission rate. In this way, the model can assess short-term and long-term impacts.

Receptor locations are evaluated by their relative distance (x,y) from the source and their elevation (z) (EPA 1988b). The modeling of particulate (radionuclide) impacts at offsite receptors at the perimeter of OU6 will be performed by dividing the entire area of OU6 into areas representative of a specific radionuclide soil concentration and estimating the cumulative impact of wind erosion from all these separate area sources. Thus, ambient radionuclide modeling at the offsite receptors will consider the cumulative impacts from all radionuclide-bearing surficial soils on OU6.

Onsite ambient radionuclide impacts from OU6 will be modeled by designating an area that conservatively represents observed surficial soil concentrations of radionuclides. The radionuclide soil concentration used for this representative location will be obtained from estimating the reasonable maximum exposure (RME) of all surficial soil radionuclide concentrations sampled on OU6. The size of the area will correspond to an average size of one of the areas designated in the offsite particulate (radionuclide) modeling. A similar approach will be used for estimating VOC concentrations within an onsite building. RME values of subsurface soil and groundwater VOC concentrations will be used to estimate an ambient VOC impact within an onsite building located on OU6.

Selection Criterion 2 — The selected models should be able to satisfy the objectives of the study.

Output from these models either as air contaminant concentrations or as deposition values at the designated exposure points will provide input for the assessment of human health risks. The ability of these models to simulate the transport and dispersion of particulate supports the objective of the modeling effort.

The multiple compounds potentially identified as chemicals of concern will be easily handled by the selected air dispersion models through a multiplicative factor (the ratio of a specific compound source term to a unit emission rate) that is multiplied by the estimated ambient impacts from a unit emission rate (i.e., because of the linear relationship of air concentration to input emission rate). In addition, each of these models can be used to evaluate the effectiveness of potential remediation strategies by simply varying the source term as a function of the remediation strategy being examined.

Selection Criteria 3 and 4 — The selected models should be verified using published equations and solutions. The selected models should be complete and well documented and preferably available in the public domain.

Both models are recommended by EPA as the most representative methods for determining respective transport and dispersion characteristics for VOCs and inorganic metals, semi-volatiles, and radionuclides in particulate form. These models have been used extensively on both non-remedial and remedial studies. (The FDM model has undergone several validation studies with favorable results. Despite these results, EPA has not officially designated FDM as a validated model.)

Selection Criterion 5 — The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

Both models are readily available since they are public domain models and do not require special procurement or licensing costs. Their use is well documented and both models are designed to execute on PC-compatible computers. Support for use of these models is also readily available. Their relative ease of use and wide acceptance of the modeling results makes them preferable over other available models.

3.6 SUMMARY OF PARAMETER VALUES

This section presents a summary of the data currently available to estimate model parameter values for groundwater, surface water, and air modeling. Where available, site-specific data collected during the Phase I RFI/RI investigations or earlier studies will be used. If site-specific data are not available, published literature values will be used in the modeling activities.

Tables 3-1, 3-2, 3-3, and 3-4 present a summary of data currently available to estimate model parameters. The available data were compiled based on a review of previous investigations and the data currently available from the Phase I RFI/RI investigation, or general literature. In the case of chemical parameter values, development of the list of chemicals of concern has not yet been finalized. Therefore, it is not possible to summarize chemical parameter data at this time. Chemical parameter data has been compiled in the draft Chemicals of Concern Technical Memorandum No. 4 for the OU6 HHRA (to be included as Appendix L of this work plan) and is currently being reviewed by EPA and CDPHE.

The data presented in Tables 3-1, 3-2, 3-3, and 3-4 are preliminary and, in some cases, are not site specific. The data values or ranges of values are not intended to be fixed or final. The ranges are presented to convey what is currently known of the potential variability in parameter values that may be used in the models.

The meteorological data to be used will be a ~~1~~ 2-year hourly meteorological data set from 1991 89 or 1992 93 from the 10 meter level of the West Buffer Zone 61 meter tower. The RFETS meteorological monitoring program includes one 61 meter tower instrumented with Prevention of Significant Deterioration quality equipment at three levels (10, 25, and 60 meters) located on the west side of the plant property, outside of the plant security fence. The 10-meter data will be merged with concurrent mixing height data from Stapleton International Airport. Stability class will be determined from sigma theta and wind speed measurements obtained from the West Buffer Zone meteorological database. Maximum wind speed data from this site may also be used to estimate wind erosion emissions.

The data used as inputs for the air models will be primarily from recent OU6 soil sampling and groundwater monitoring programs performed as part of the OU6 RFI/RI investigation. These data include:

- Surficial soil grain size data and analytical data for metals, radionuclides, semi-volatiles, and VOCs from all the IHSS locations within OU6.

- Groundwater VOC concentration data gathered from the recently installed 11 OU6 monitoring wells will be used to estimate vapor-phase concentrations for the onsite building modeling.

- Subsurface soil VOC concentration data for the onsite building modeling will be obtained from soil boring sampling conducted at locations near the surficial soil sampling locations in the OU6 IHSSs.

TABLE 3-1
PARAMETER VALUES FOR GROUNDWATER MODELING

Parameter	Units	Range of Values	Source
Properties of Colluvium/Alluvium			
Hydraulic Conductivity	cm/sec	10^{-5} - 10^{-3}	Freeze and Cherry (1979) and OU6 and OU2 site-specific data
Effective Porosity	%	3 - 10	OU6 and OU2 site-specific data
Bulk Density	lbs/ft^3	94 - 130	Das (1985) and OU6 and OU2 site-specific data
Retardation Factor	Dimensionless	1-10	OU2 site-specific data for specific contaminants
Biodegradation Half-Life	Days	7-1825	Howard, et al. (1991) for specific contaminants

TABLE 3-2
SURFACE WATER MAJOR PARAMETER VALUES

Parameter	Units	Range of Values*
Precipitation/Runoff		
Nominal soil moisture storage (LZSN,UZSN)	inches	.01 - 100
Infiltration capacity index (INFILT)	in/hr	.0001 - 100
Groundwater recession rate (AGWRC)	per day	.001 - 1.0
Interception storage capacity (CEPSC)	inches	0 - 10
Trade-off between interflow and surface runoff (INTFW)	none	min of 0 (no max)
Interflow recession parameter (IRC)	per day	0 - 1.0
Air temperature below which precipitation will be snow (TSNOW)	deg. F	30 - 40
Fraction of the land segment which is shaded from solar radiation (SHADE)	none	0 - 1
Interception storage capacity of an impervious surface (RETSC)	inches	0 - 10
Soil erosion		
Initial storage of detached sediment (DETSB)	tons/acre	min of 0 (no max)
Fraction of detached sediment which reattaches each day (AFFIX)	per day	0 - 1
Flux to/from atmosphere from/to detached storage (NVSI)	lbs./acre-day	none
Coefficient for detached sediment washoff (KSER)	none	0 - 1
Coefficient for soil scour (KGER)	none	0 - 1
Hydrodynamics		
Median diameter of bed sediment (DB50)	inches	.0001 - 100

TABLE 3-2 (CONTINUED)

Parameter	Units	Range of Values*
Hydrodynamics (continued)		
Channel characteristics as functions of the water surface elevation:		
depth	feet	none
surface area	sq. feet	none
volume	cubic feet	none
Contaminant Fate		
Ratio of volatilization rate to oxygen reaeration rate (CFGAS)	none	min of 0 (no max)
Partitioning coeffecient between dissolved and suspended states (KDJ)	l/mg	0 - (no max)
First-order biodegradation rate constant (KBIO)	per day	0 - 1

* Parameter ranges were obtained from the HSPF User's Manual, 1984.

OU6 site-specific data will be used where available.

TABLE 3-3
PARAMETER VALUES FOR SOIL GAS MODELING

Parameter	Units	Range of Values	Source
Surface Area of IHSS	cm^2	10^6 - 10^{10}	Phase II RFI/RI Workplan (DOE 1992a)
Surface Cap Thickness	cm	10^1 - 10^2	OU6 site-specific data
Soil Cap Air-filled Porosity	%	25 - 35	OU6 site-specific data
Vapor Diffusion Coeff. in Air	cm^2/sec	10^{-2} - 10^{-1}	Compound-specific; SEAM (1988a) or Lyman (1982)
Thickness of contaminated soil	cm	10	OU6 site-specific data
Weight fraction of contaminant in waste	g/g	10^{-9} - 10^{-5}	OU6 site-specific data
Intrinsic permeability of soil	cm^2	10^{-9} - 10^{-7}	OU6 site-specific data
Liquid-phase concentration of contaminant	g/cm^3	10^3 - 10°	OU6 site-specific data

TABLE 3-4
PARAMETER VALUES FOR AIR TRANSPORT AND DISPERSION MODELING

Parameter	Units	Range of Values	Source
Joint frequency distribution of stability class, wind speed and direction	Unitless	Fraction of one; total sum of all entries is one	1992 West Buffer Zone data from EG&G
Mean annual morning and afternoon mixing heights	m	250 - 4000	Data from Stapleton for 1992
Particle size	μm	1 - 80	OU6 site-specific data
Particle size distribution	Unitless	Fraction of one; total sum of all entries is one	OU6 site-specific data
Contaminated area (surface dimensions)	m^2	10^3 - 10^4	OU6 site-specific data
Ground Coverage	%	0 - 100	Aerial photos; onsite (unvegetated area) observations
Receptor location, above source, distance from source	m	1 - 10^3	Scaled maps of elevation of study area
Surface roughness	cm	1 - 100	Site observations correlated with documented criteria on assigning appropriate surface roughness value

4.0 SUMMARY

In order to model the fate and transport of contaminants at OU6 to specific exposure point locations for the HHRA, several models have been evaluated for application to groundwater, surface water, and air modeling. Model selection was based on the following five criteria:

1. The selected models should be able to incorporate key processes known to occur at the site.
2. The selected models should be able to satisfy the objectives of the study.
3. The selected models should be verified using published equations and solutions.
4. The selected models should be complete and well documented and preferably available in the public domain.
5. The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

The following models were selected to meet the requirements of the modeling study:

- A simple one-dimensional analytical groundwater model will be run to determine the potential for vinyl chloride to migrate downgradient or to volatize directly from the vadose zone into the atmosphere.
- The HSPF10 model for surface water fate and transport.
- The SEAM models for soil gas fate and transport, a box model for onsite ambient air contaminant fate and transport, and FDM for offsite ambient air contaminant fate and transport of OU6 source air emissions.

Data currently available for use as input for the modeling activities were evaluated. Tables 3-1, 3-2, 3-3, and 3-4 summarize the data currently available to estimate model parameters. Data from the Phase I RFI/RI investigation will also be used in the modeling effort.

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